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Date: December 7, 1984

To: Members of the Technical Subcommittee Lease-Sale
Planning and Research Committee Alaska Oil and Gas
Association

Subject: Transmittal of Sandia's Proposal for: Seafloor
Earthquake Measurement in the Southern Bering Sea and
the Aleutian Shelf

Gentlemen:

On September 27 I made a presentation at your regular meeting in Lebanon, NH. During that talk I described the current Department of Energy (DOE) effort, directed by Sandia, to develop strong motion earthquake instrumentation applicable to the arctic seafloor. Also covered was how this instrumentation might be applied to the southern Bering Sea where strong motion data are scarce.

Since that time, DOE has received requests from participating members of LPRC for formal proposals for a joint industry-government project to deploy this instrumentation and gather data in the southern Bering Sea. The enclosed proposal is our response to those requests. It is our intent in making this proposal to provide a well-rounded project that is responsive to the immediate and long-term needs of both government and industry for seafloor earthquake data. We believe that you will find that the technical merit in this project justifies the cost, and that the leverage provided by government participation is substantial.

We welcome your comments on this proposal. DOE is prepared to provide you with a draft agreement stating terms and conditions at your request.

Sincerely yours,



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A PROPOSAL FOR
SEAFLOOR EARTHQUAKE MEASUREMENT
IN THE SOUTHERN BERING SEA
AND THE ALEUTIAN SHELF

Proposal No. 6241126 WA
November 26, 1984

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1.0 PURPOSE

The purpose of this project is to recover strong motion earthquake data applicable to the Southern Bering Sea and to seafloor soils near the Alaskan Peninsula and Aleutian Islands. Sites will be chosen and data will be collected and analyzed with a goal of supplementing the seismic design criteria for bottom-founded offshore structures that might be used for petroleum exploration, drilling, and production. The Sandia Seafloor Earthquake Measurement System (SEMS) will be used as a remote seismic station for collecting the necessary data. Sandia will provide technical program management and the principal investigators.

2.0 BACKGROUND

2.1 Problem Statement

There is general agreement in government and industry that a need exists for a better definition of the Alaskan earthquake environment. This position is well documented by the OASES study (Ref. 1) and the Department of Commerce geologic hazard study of 1982 (Ref. 2). Earthquakes are common to the region, and may originate from local faulting, volcanism, or the larger tectonic processes caused by the subduction of the Pacific plate under the thicker plate of the North American continent.

Alaskan earthquakes tend to be greater in magnitude and duration and more frequent than the familiar quakes of southern California. It is also expected that their acceleration time histories will differ. Local faulting produces relatively infrequent earthquakes, but the magnitude may be in excess of 7.0. Volcanically induced earthquakes are similarly infrequent, and generally of magnitude 6.0 or less. Subduction zone events, however, have roughly a five-year return period for a magnitude 6.0 event, and a great earthquake of magnitude 8.0 or more is predicted near the Shumagin islands during the next 20 years (Ref. 3, 4).

Because of the remoteness of this region, earthquake data are scarce. This requires the extrapolation of California and Japanese data to forecast the response of soils in lease-sale areas. Although this practice is becoming more sophisticated, experimental verification is needed, especially in the case of time history measurements so necessary for good dynamic analyses of structures.

In addition to the need for specific data on the Alaskan environment, there exists a more general set of problems that can only be addressed by seafloor earthquake measurements. The response of seafloor soils to strong ground motion must, at

this time, be inferred from our knowledge of land-based soil response, model analyses, and experiment. It is to be expected that the motion of saturated seabed soils will differ from that measured on land, and that the overlying water mass will reduce the intensity of vertical accelerations. Strong motion measurements would add significantly to the narrowing of uncertainty as to the general nature of seafloor soil motion.

2.2 Technical Goals

The principal goal of this project is to capture complete acceleration time histories from a magnitude 6.0 or greater earthquake at close range. The data collected will be reduced to provide:

1. Acceleration, velocity, and displacement time histories of the free field motion.
2. Acceleration, velocity, and displacement versus frequency and period response spectra.

The secondary goals of the project are:

1. To collect data at various distances from a source for comparison with models of wave propagation.
2. To obtain data in representative areas of the St. George and North Aleutian Basins.
3. To examine measured free field response in light of predictive models for saturated soils under hydrostatic pressure.

2.3 Site Selection

The technical goals previously enumerated would be achieved by deploying an array similar to that shown in Figure 1 and further described in Table 1. The sites presented in Figure 1 are intended for two separate purposes. The stations south of the Aleutians are situated to maximize their chances of recording strong ground motion from the relatively frequent subduction zone events. The stations north of the Aleutians are selected to satisfy the secondary goals stated in Section 2.2. The numbers of SEMS deployed will be influenced by the number of industry participants; however, six stations are considered the minimum required for the project, and ten stations the maximum that could be fielded and maintained.

In addition to the above criteria for a SEMS site, the following also apply:

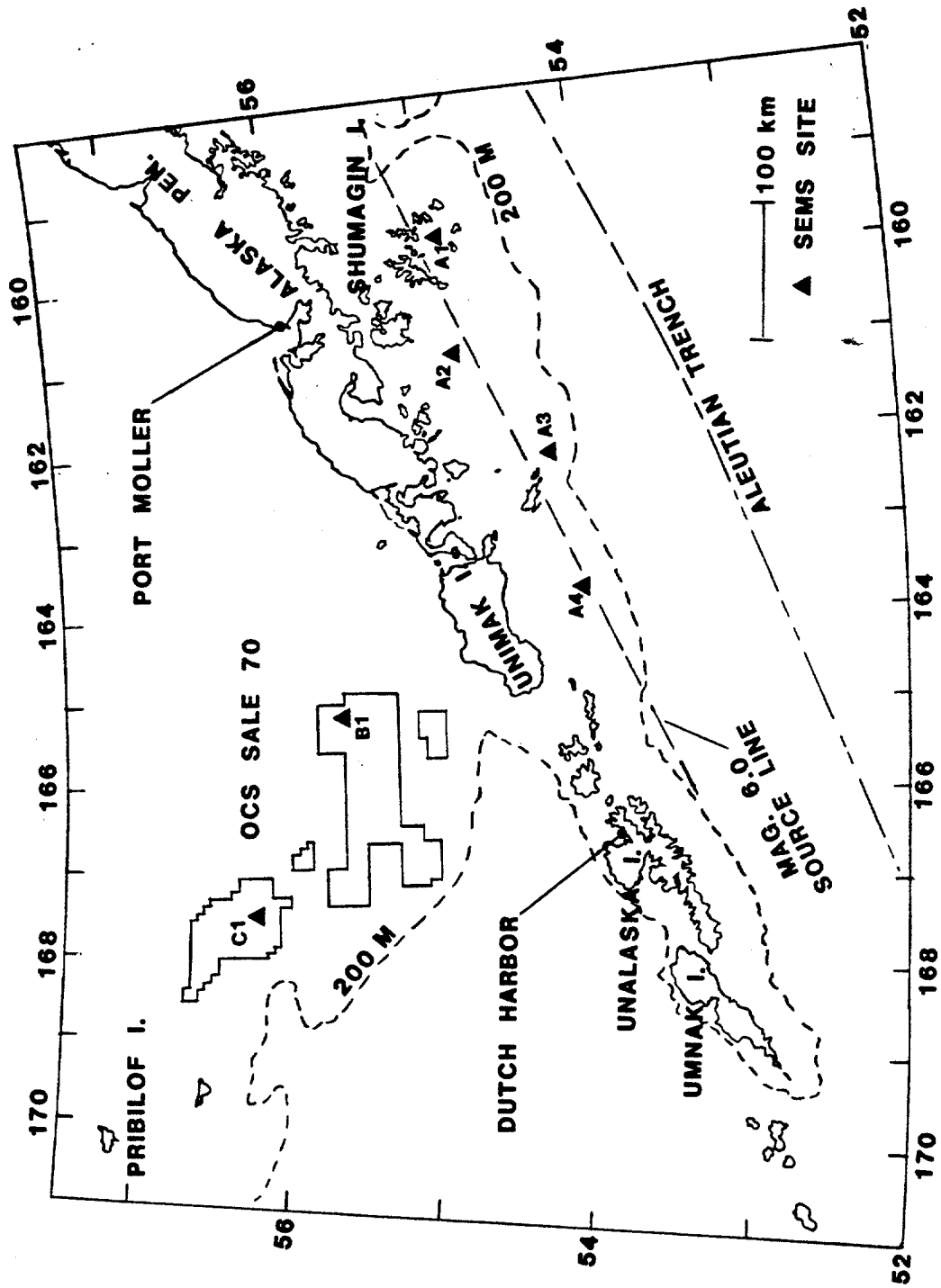


FIG. 1 SOUTHERN BERING SEA REGION

Table 1.

BERING SEA ARRAY

SITE	INSTALL. DATE	LATITUDE (DEC.DEG)	LONGITUDE (DEC.DEG)	WATER DEPTH (M)	MAXIMUM PROBABLE ACCEL.	SOIL TYPE
					(G)	
A1	8/85	54.93	159.68	46	0.20	SAND AND GRAVEL ?
A2	8/86	54.85	160.93	82	0.20	SAND, 10% SILT
A3	8/88	54.35	162.05	66	0.20	SAND, 10% SILT
A4	8/87	54.20	163.65	79	0.20	SAND, 10% SILT
B1	8/86	55.65	165.40	111	0.05	FINE, SILTY SAND
C1	8/87	56.30	167.50	129	0.03	FINE, SILTY SAND

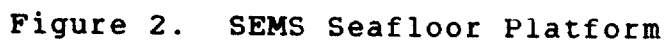
1. The presence of a competent soil which will provide good coupling with the seismic probe.
2. Water depths in excess of 150 feet in order to duplicate leasing area locations and water column heights.
3. Isolation from geographical features that create breaking waves, high bottom currents, or tilted terrain.
4. Proximity to the seismic array in the Shumagin Islands maintained by Lamont-Doherty Geological Observatory.

2.4 Description of SEMS

The Sandia Seafloor Earthquake Measurement System (SEMS) is a self-contained remote seismic station (Figure 2). It is capable of measuring and recording strong ground motions with a three-axis probe (Figure 3) buried six feet into the underlying soil. Recorded measurements are retrieved at 3-4 month intervals by acoustically interrogating the SEMS with a portable shipboard command unit that can also reset or adjust operating parameters for the SEMS control system. References 5 and 6 describe the configuration and capability of the hardware in detail, and can be provided on request.

The SEMS Seafloor Platform shown in Figure 2 consists of two pressure vessels housing batteries and electronics, an acoustic telemetry system, and a recovery float and line. All are supported by a smooth frame that provides protection from fishing cables and nets that may be dragging the bottom. The Seafloor Platform communicates with the seismic probe, which is buried six feet below the platform, via an electrical cable. Basic system specifications appear in Table 2.

Once in operation, a microprocessor controller monitors a three-axes accelerometer package within the probe. When incoming signals exceed 1.5 times the background level for two seconds, an event is declared and buffer recording begins. At the same time a magnetic bubble memory is activated and searched. Should the incoming event be stronger in magnitude than any other earthquake(s) in memory, it will replace the weakest event(s). A total of 1520 seconds of memory are available, partitioned into 24-second blocks. When the incoming signals have dropped back to 1.2 times the earlier background noise level, the controller declares the event over, and shuts down the nonvolatile memory to conserve power.



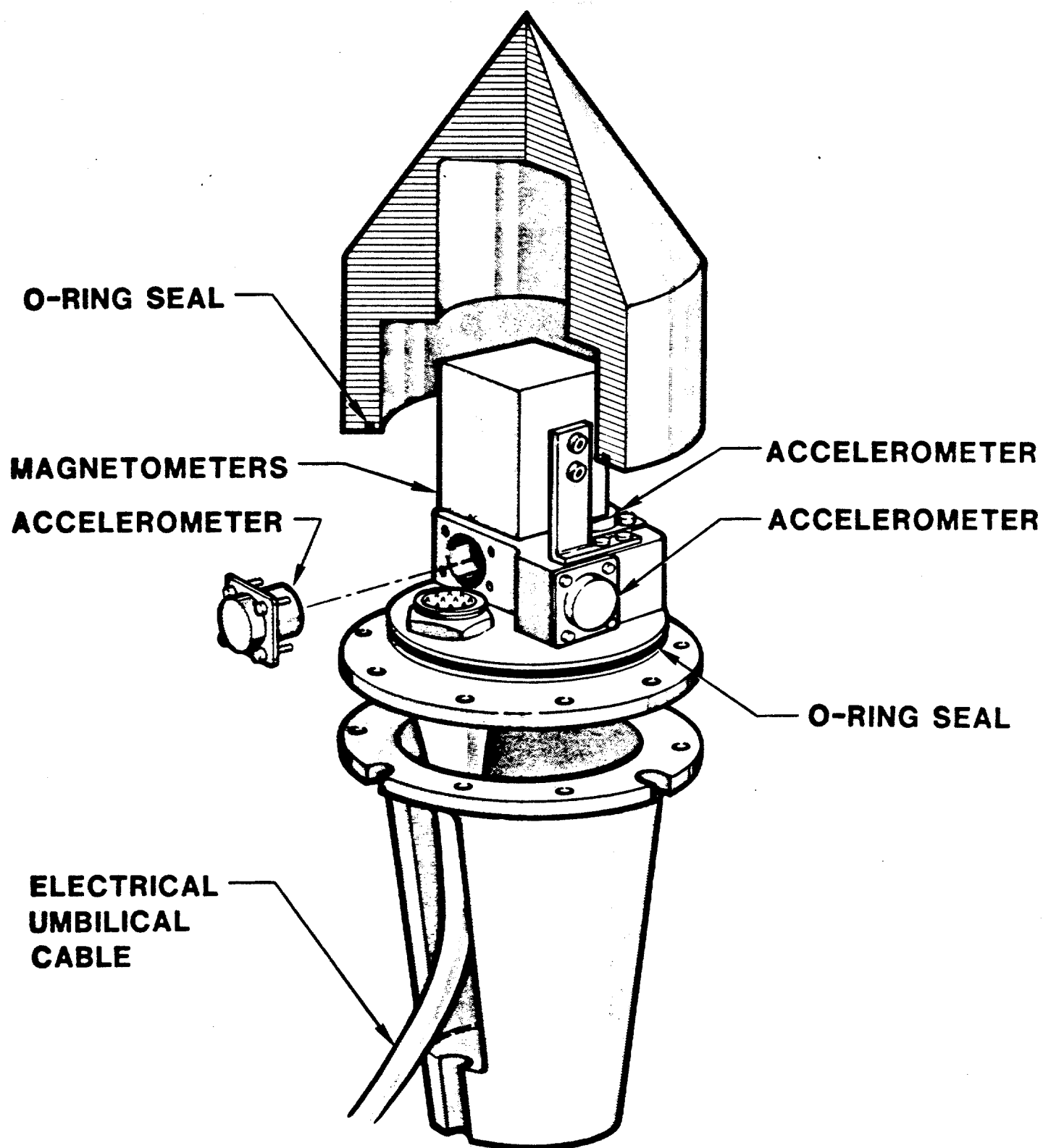


FIG. 3 SEISMIC PROBE

Table 2.

SEMS : PHYSICAL DESCRIPTION AND OPERATING SPECIFICATIONS

COMPONENT OR CHARACTERISTIC	DESCRIPTION OR VALUE
1. COST :	
HARDWARE	\$ 68,000
ASSEMBLY	\$ 35,000
DEPLOYMENT	\$ 7,000
TOTAL COST DEPLOYED	\$ 110,000
TOTAL LIFE CYCLE COSTS	\$ 175,000
2. SYSTEM LIFE	BATTERIES AND PRESSURE RATED SEALS DESIGNED FOR 5 YEARS OPERATION, STATED LIFE : 4 YEARS
3. CONTROLLER	RCA 1802 MICROPROCESSOR MONITORS PROBE AT A SAMPLING RATE OF 100/SEC PER ACCELEROMETER AND CONTROLS MEMORY AND TELEMETRY FUNCTIONS
4. MEMORY	1520 SEC OF MAGNETIC BUBBLE MEMORY ARRANGED IN ADDRESSABLE 23.8 SEC BLOCKS
5. TELEMETRY SYSTEM :	
SLANT RANGE	1000 METERS
ANTENNA PATTERN	140 DEGREE CONICAL BEAM
TRANSMISSION RATE	1200 - 2400 BITS PER SECOND
6. PROBE MAGNETOMETER	2-AXIS, 1.5 DEGREE ORIENTATION MEASUREMENT ACCURACY
7. PROBE ACCELEROMETERS :	
MODEL	ENDEVCO 7751-500 SOLID STATE
DYNAMIC RANGE	10,000 OVER 0.0001 TO 10.0 G
FREQUENCY RESPONSE	0.2 - 1500 HZ (+/- 5%) 0.1 - 1500 HZ (+/- 10%, CALIBRATED)
FREQUENCY RANGE	5 - 1500 HZ, PHASE SHIFT <2 DEGREES 0.1 - 20 HZ, PHASE SHIFT CALIBRATED
NATURAL FREQUENCY	7000 HZ
8. TIME ACCURACY	(+/-) 100 MILLISEC RELATIVE TO WWV TIME

The controller also operates the acoustic telemetry system. Upon command from the surface, SEMS will respond with its data and information on its operating condition. Memory blocks can then be remotely cleared, the internal clock re-zeroed to WWV time, battery status read, and certain operational trigger levels can be reset, if necessary.

3.0 SCOPE OF WORK

Given the earlier background discussion and statement of goals, the specific tasks that Sandia proposes to undertake are as follows:

- A. Build, test, deploy, and monitor a minimum array of 6 SEMS units in the Southern Bering Sea.
- B. Add an additional SEMS to the array for each additional Contributor in excess of six (6) Contributors, up to a maximum of four (4) additional SEMS units.
- C. Operate each SEMS for four (4) years or until system failure occurs or appears imminent.
- D. Select SEMS locations based on the following criteria:
 - 1. Achieving a high probability of recording a magnitude 6.0 or greater earthquake near its source.
 - 2. Obtaining measurements of long period earthquake waves distant from the source.
 - 3. Collecting real-time earthquake time histories.
 - 4. Obtaining data that can be used to check and extend earthquake response models of the offshore leasing areas.
 - 5. Instrumenting representative locations in St. George and North Aleutian Basins.
- E. Retrieve a six to ten (6-10) foot long core sample from the sediments at each SEMS site.
- F. Determine SEMS calibration factors for the soil types and locations of interest
- G. Collect data from each operational SEMS unit no less than three times a year, weather and ocean conditions permitting.

- H. From the data collected, provide the following to each Contributor in a semiannual report:
 - a. Acceleration-time histories of the maximum events recorded at each station during a monitoring period, corrected for instrument calibration.
 - b. Chronological tabulations of all events recorded at all stations during each monitoring period.
 - c. Integrated velocity and displacement histories generated from the acceleration histories in item a.
 - d. Soil response spectra for the events recorded.
 - e. A review of current data viewed in the context of past measurements and predictive models of seafloor earthquake response.
 - f. The results of any analyses or modeling studies performed in support of the project.
 - g. Digital tapes upon request of raw and processed digital data.
- I. Provide each Contributor with a quarterly status report that summarizes current work in progress.
- J. Convene an annual Project Review Meeting each year in November to discuss results of past work, goals for the coming year and to elicit recommendations from the contributors.
- K. Observe the following deployment schedule, adjusting the number of SEMS deployed to meet the total requirement specified in items A, B.
 - 1985 Deploy 1-2 SEMS
 - 1986 Deploy 2-3 SEMS
 - 1987 Deploy 2-3 SEMS
 - 1988 Deploy 1-2 SEMS
- L. In lieu of semiannual reports in June of 1987 and 1989, and 1991, issue Interim Project Reports which summarize all activities, results, and assessments of soil response up to that time.
- M. Issue a Final Project Report in September, 1992. Terminate the Project at that time.

4.0 SCHEDULE AND COST

The schedule of major milestones is given in Table 3. The schedule assumes that contracts will be finalized and executed with at least six industry participants by March 30, 1985, thereby allowing time for the preparations necessary to install the first unit in August, 1985. Should that timing not be met, then the schedule will be revised to allow two units to be installed in each of the summers of 1986, 1987, and 1988. The milestones will remain much the same except for the change in deployment schedule.

The Department of Energy has been providing funds for SEMS projects for the last seven years, assisted by the Department of Interior. Funding from these sources has gone to pay the costs of development, analysis, and technical manpower, as opposed to specific hardware for joint industry projects. It is proposed that this division of funding continue, with industry paying for those costs directly attributable to the life-cycle of the SEMS units required for this project. This would include those costs incurred in:

1. Procuring hardware
2. Assembling SEMS units
3. Shipping and deployment charges
4. Data gathering costs for each unit
5. Direct costs for data reduction and reporting
6. Costs of supporting hardware for installation and data gathering.

Table 4 gives a breakdown of total life cycle costs for an array of six SEMS. The table also provides a funding schedule that meets DOE requirements that payment be received in advance of expenditures.

Assuming that industry contributions are divided among six companies, for the years of FY85 through FY89, the schedule of company payments would be as follows:

	FY85	FY86	FY87	FY88	FY89
Cost per Company	\$ 25	\$ 45	\$ 45	\$ 35	\$ 25
(in thousands)					

Over the life of the program, total industry contributions would amount to \$1,050,000. By comparison, related government expenditures needed to support this project would amount to approximately 3 million dollars.

Table 3.

SCHEDULE OF MILESTONES BY FISCAL YEAR

MILESTONE	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92
EXECUTE CONTRACTS
FINALIZE ARRAY	. X	.	.	.	.	.	.	.
DEPLOY UNIT 1	.	X.	.	.	.	.	.	.
ANNUAL MEETING #1	.	X	.	.	.	.	.	.
PROBE CAL. ANALYSIS	.	.	X	.	.	.	.	.
DEPLOY UNITS 2,3	.	.	X.	.	.	.	.	.
ANNUAL MEETING #2	.	.	X	.	.	.	.	.
SOIL RESPONSE ANAL.	.	.	.	X	.	.	.	.
INTERIM REPORT	.	.	.	X	.	.	.	.
DEPLOY UNITS 4,5	.	.	.	X.	.	.	.	.
ANNUAL MEETING #3	.	.	.	X	.	.	.	.
REVIEW MODELS, DATA	X	.	.	.
DEPLOY UNIT 6	X.	.	.	.
ANNUAL MEETING #4	X	.	.	.
INTERIM REPORT	X.	.	.
ANNUAL MEETING #5	X	.	.
ANNUAL MEETING #6	X	.
REVIEW MODELS, DATA	X
ANNUAL MEETING #7	X
FINAL REPORT	X

Table 4.

TABLE 4.

BREAKDOWN OF RECOVERABLE COSTS FOR THE DEPLOYMENT
OF SIX "SEMS" UNITS IN THE BERING SEA

ITEM	FY85 (\$K)	FY86 (\$K)	FY87 (\$K)	FY88 (\$K)	FY89 (\$K)	FY90 (\$K)	FY91 (\$K)	FY92 (\$K)
SEMS HARDWARE	68	136	136	68				
ELECTRICAL ASSEMBLY	15	30	30	30				
MECHANICAL ASSEMBLY	5	10	10	5				
QUALITY TESTING	15	30	30	15				
SHIPPING TO ALASKA	2	4	4	2				
SEAFLOOR INSTALLATION	5	10	10	5				
SUPPORTING HARDWARE	25	15						
DATA GATHERING		7	15	20	20	15	10	7
DATA REDUCTION		7	12	18	20	18	15	10
REPORTING	5	10	15	10	15	10	15	25
SUMMED COSTS	140	259	262	173	55	43	40	42
TAX, SURCHARGE (3.5%)	5	9	9	6	2	2	1	1
TOTAL COSTS	145	268	271	179	57	45	41	43
INDUSTRY FUNDS	150	270	270	210	150	0	0	0
ACCUMULATED COSTS	145	413	684	863	920	965	1006	1049
ACCUMULATED FUNDS	150	420	690	900	1050	1050	1050	1050
YEARLY BALANCE	5	2	-1	31	93	-45	-41	-43
ACCUMULATED BALANCE	5	7	6	37	130	85	44	1

5.0 CONTACTS

Technical questions concerning this proposal should be referred to

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Should you wish to consider or enter into an agreement on this proposal, that request should be addressed to;

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6.0 REFERENCES

1. "Offshore Alaska Seismic Exposure Study," prepared for the Alaska Subarctic Offshore Committee by Woodward-Clyde Consultants, March 1978.
2. "Seafloor Geologic Hazards on the North Aleutian Shelf," prepared for the National Oceanic and Atmospheric Administration by ERTEC Western, Inc., June 1983.
3. J. Davis, L. Sykes, L. House, and K. Jacob, "Shumagin Seismic Gap, Alaska Peninsula: History of Great Earthquakes, Tectonic Setting, and Evidence for High Seismic Potential," Journal of Geophysical Research, Vol 86, No. B5, p 3821, May 1981.
4. Klaus Jacob, "Estimates of Long-term Possibilities for Future Great Earthquakes in the Aleutians," Geophysical Research Letters, Vol 11, No. 4, p. 295, April 1984.
5. David E. Ryerson, "Seafloor Earthquake Measurement System," Sandia National Laboratories, SAND81-1810, December 1981.
6. David E. Ryerson, and Gene C. Hauser, "A High-Data-Rate Wide-Angle Underwater Acoustic Telemetry System," Sandia National Laboratories, SAND84-0994, July, 1984.

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